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ABSTRACT

The relative contributions of four individual difference variables to ability to solve analogically related problems in four separate problem sequences and for spontaneous and assisted transfer was examined. Subject were 116 university undergraduates enrolled in an introductory psychology course who volunteered to participate for course credit and 65 high school seniors who volunteered to participate for extra credit from their social studies teacher. Specifically examined was whether combinations of individual difference variables served as significant predictors of problem-solving success in four different source-target problem sequences. For spontaneous transfer, the results indicate that under certain circumstances different combinations of individual difference variables contribute to the ability to predict whether a subject would provide a particular solution to a target problem. For assisted transfer, individual differences do not account for the ability to predict whether a subject would provide a particular solution to a target problem. Results are discussed in terms of why the individual difference variables enhance prediction for spontaneous transfer only under certain circumstances. In addition, suggestions for pursuing this line of inquiry are provided. Four tables present study data. Appendix A contains a logic problem from the study, and Appendix B contains the source and target analogues. (SLD)

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Individual differences in transfer via analogy

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Abstract

This study examined the relative contribution of four individual difference variables to ability to solve analogically related problems in four separate problem sequences and for spontaneous and assisted transfer. Specifically, it tested whether combinations of individual difference variables served as significant predictors of problem solving success in four different source-target problem sequences. For spontaneous transfer, the results indicated that under certain circumstances different combinations of the individual difference variables were contributing to ability to predict whether a subject would provide a particular solution to a target problem. When considering assisted transfer, individual differences were not accounting for ability to predict. The results are discussed in terms of why the individual difference variables enhance prediction for spontaneous transfer only under certain conditions. In addition, suggestions for pursuing this line of inquiry are provided.

Individual differences in transfer via analogy

The study of knowledge transfer in cognitive domains such as problem solving, and to a lesser extent, reading to learn, has advanced theory concerning schema induction. The majority of work with transfer, as such, has been in the domain of problem solving, specifically how analogy assists to promote the transfer of knowledge structures. The basic view is that if an individual can see an analogous relationship between two problems and has access to the solution for one of the problems, then the other problem should be easier to solve. More simply stated, analogical reasoning is a form of inference that allows an individual to extract implications from a single case (Klein, 1987). Transfer via analogical reasoning enables the individual to use inferences under diverse circumstances.

Problem solving via analogical transfer has been extensively researched by Holyoak and colleagues (e.g., Bassok & Holyoak, 1989; Gick & Holyoak, 1980; 1983; Holyoak & Koh, 1987). A close examination of the Gick and Holyoak study of 1983, however, exposes some interesting differences in ability to solve transfer problems. In Experiments 2 and 3 identical conditions were used. Specifically, subjects summarized the same source problem which was directly analogous to a target problem and then attempted to solve the same target problem. In Experiment 2, 29 percent of the subjects were able to solve the target problem on their first attempt (spontaneous transfer), while 40 percent of the subjects in Experiment 3 were able to spontaneously solve the problem. Subjects not solving the problem on their initial try were then given a hint that the first problem studied might help them when considering the target problem (assisted transfer). After this hint, 50 percent of the remaining subjects from Experiment 2 were able to solve the problem, while only 36 percent of those from Experiment 3 were successful. We found this to be a curious occurrence. Anderson bolstered that curiosity by his assertion that it "requires a little sophistication to use analogy correctly" (1990, p. 242). What makes up that sophistication is, however, unclear. Our discussions led us to speculate that these different percentages might be related to individual differences between subjects. When considering the role of individual differences in the problem solving literature with special attention to transfer, however, the research has focused on dimensions such as: experts versus novices (e.g., Anderson, Farrell, & Sauers, 1984; Chase & Simon, 1973; Larkin, McDermott, Simon, & Simon, 1980) and context effects both in terms of the learning environment and passage (analogue structure) similarities (e.g., Blake & Clark, 1990; Spencer & Weisberg, 1986; Stein, Way, Benningfield, & Hedgecough, 1986; Weisberg, DiCamillo, & Phillips, 1978). While this has produced a wealth of information, other individual

difference dimensions exist which may easily lend themselves to experimentation and may cast knowledge transfer via analogy in a new light.

Individual differences. The question we faced was what individual difference variables might assist in explaining the discrepancy described earlier. Previously researchers have considered differences in the quality of a source analogue summary (Gick and Holyoak, 1983). In addition, three other variables, analogical reasoning (verbal) ability, creativity, and ability to solve logic problems, seemed promising for a variety of reasons.

The quality of the summary produced by the subject for the source analogue has received considerable attention (e.g., Gick & Holyoak, 1983; Spencer & Weisberg, 1986). The basic premise is that subjects who identify the two critical features of the convergence schema (converging forces and multiple or split forces) have produced what is considered to be a better quality summary of the source analogue. When percentages of subjects achieving spontaneous transfer was considered, subjects who produced a summary with the two critical features were more likely to spontaneously solve the target problem than those who identified only one or neither of the critical features. When considering assisted transfer, no differences appeared (Gick & Holyoak, 1983). This can not be ignored when considering the impact of individual differences. Subjects who create better quality summaries may have a more elaborately encoded schema from which to draw the analogy necessary for transfer.

Hunt and his colleagues (e.g., Hunt, 1978; Hunt, Lunneborg, & Lewis, 1975; Lansman & Hunt, 1982;) have effectively demonstrated that individual differences in verbal ability have a dramatic impact on fundamental information processing capabilities (e.g., storing and manipulating information in working memory). In view of these studies, we felt that verbal reasoning ability would serve as a promising individual difference variable. Since the problems to be used (i.e., from Holyoak and colleagues) required identification of analogous relationships, the best test would be one that addressed the issue of analogies on some level.

Creativity and problem solving have been linked by a number of researchers (e.g., Glover, 1980; Keane, 1988; Weisberg, 1988). Individuals with higher levels of creative ability have, most importantly, been described as having the ability to see relationships, perhaps structures, between ideas or objects that other less creative individuals miss (Glover, 1980). When dealing with analogous problems, the problem solver is required to identify structural relationships between problem analogues. Accordingly, those who demonstrate greater ability in this respect (perhaps the more creative individuals) should have a better chance at solving the problem. Therefore, individuals with higher levels of creative ability might perform significantly better in attempts to solve analogically related problems.

One further area that seemed worthy of investigation and inclusion in the experimental procedure was the subjects' ability to solve a more traditional problem. The logic problem used in the research required the subject to engage in deductive reasoning. These logic problems are written such that enough information is available for solving the problem, but the information is restricted in some fashion. The problem solver must start with what is given and test some hypotheses about possible courses which would add information to the problem representation. As more is added to the problem representation, the solver moves closer to a potentially correct solution. This can be understood in light of what Newell and Simon (1972) referred to as a means-ends analysis. In this approach to problem solving the solver is required to move in a progressive fashion from the initial problem state to the goal state. As each "subproblem" is solved, the solver moves closer to the goal until all subproblems have been solved which means that the goal has been reached.

Problem type. In the Gick and Holyoak studies, two different types of problem sources and targets seem to have been used. One type consisted of problems that seem familiar somehow. They seem like descriptions of historical events, something that a potential subject might have learned about (or heard about) in a social studies context. The problems in this class dealt with a general attempting to capture a fortified city and an expert fire fighter (who was seen fighting oil well fires in Kuwait on the evening news shortly after the end of the Gulf War) attempting to extinguish a blazing oil-well fire. The other problems seemed much more technical or scientific--less familiar. The problems in the second class dealt with surgeons and lab technicians who work with sophisticated equipment (a tumor destroying ray and an ultrasound machine respectively) with which most people have little practical or educationally related experience. It seemed reasonable that subjects might experience greater levels of success when attempting to solve problems that seemed familiar or easier to relate to existing knowledge. A preliminary investigation supported the following: (a) subjects seldom instinctively provide the convergence solution to either target problem to be used in the experiment, (b) the four problem analogues (the surgeon, the technician, the general, and the fire fighter) can be seen as two pairs of similar problems, and (c) subjects see the surgeon and the technician as less familiar and more scientific (as per their descriptions) than the general and the fire fighter.

Method

This experiment was designed to explore the hypothesis that measures of individual differences would serve as powerful predictors of success in solving analogically related problems. A "correct solution" is defined in this

study as providing the convergence solution which suggests successful transfer of the problem structure from source to target. Specifically, it was hypothesized that different combinations of individual difference variables would contribute to ability to predict problem solving success. If individual differences are making a contribution to prediction, we hypothesized that it would be positive (correlationally speaking) and that the patterns of contribution to prediction of success would vary between problem solving sequences. Further, we hypothesized that subjects might experience greater levels of success when attempting to solve problems that seemed familiar or easier to relate to existing knowledge (the fire fighter problem) than those that seemed less familiar (the technician). If these hypotheses were upheld, the results would show different combinations of individual difference variables accounting for ability to predict problem solving success depending on which problem served as the source and which served as the target.

Subjects and Setting

Subjects were 116 university undergraduates (the majority of whom were first year students) enrolled in an introductory psychology course who volunteered to participate for course credit and 65 high school seniors who volunteered to participate for extra credit from their social studies teacher. Again, distinct yet comparable subjects (high school seniors and first year college students) were chosen to ensure that the range of ability on the measures of individual differences was not restricted. For the university subjects, experimental tasks were conducted during two sessions (one week apart) in small groups of 5 to 15 students over a period of 5 weeks in a typical university classroom. The high school subjects participated during their regular social studies class on two separate occasions one week apart.

Materials

Subjects engaged in three tests of individual differences. The verbal reasoning subtest of the Differential Aptitude Test, Form S (Bennett, Seashore, & Wesman, 1973), which consists of 50 analogy problems, was used. Items required identification and extension of relationships, for example, "? is to future as regret is to ?." The ?'s are replaced by selecting from five options presented in a multiple-choice format. The second measure was the unusual uses subtest of the Torrance Test of Creative Thinking, Form B (1974). This subtest asks subjects to think of as many interesting and unusual uses for tin cans as possible. A logic problem, "Counter Intelligence" (Duncum & Gresty, 1987) required subjects to use deductive reasoning to determine the first and last names of 4 shop owners and discover what type of shop each owned (see Appendix A).

Source and target analogs were taken from Gick and Holyoak (1983) and Holyoak and Koh (1987). The source

problem was either "the general" or "the surgeon" (Gick & Holyoak, 1983). The target problem was either "the fire fighter" (Gick & Holyoak, 1983) or "the technician" (Holyoak & Koh, 1987). This resulted in 4 source-target problem sequences: (a) the general (familiar, source analogue) and the fire fighter (familiar, target analogue), (b) the general (familiar, source analogue) and the technician (less-familiar, target analogue), (c) the surgeon (less-familiar, source analogue) and the fire fighter (familiar, target analogue), and (d) the surgeon (less-familiar, source analogue) and the technician (less-familiar, target analogue). The problems were essentially identical to those used by Gick and Holyoak (1980; 1983) or Holyoak and Koh (1987) with only slight modifications (see Appendix B).

Procedure

During the first experimental session, subjects were given 30 minutes to complete the verbal ability test. Ten minutes were allocated for subjects to take the Unusual Uses Subtest. Subjects were given 10 minutes during which they attempted to solve the logic problem, "Counter Intelligence." Each task was followed by a brief break. The tasks were counterbalanced such that 6 sequences were established. Groups of subjects were randomly assigned to one of the individual difference testing sequences.

Between experimental sessions, the verbal ability test was scored. Subjects were then randomly assigned to solve one of the two problems such that approximately equal numbers of subjects at the various levels of verbal ability were in each problem sequence group. This was done in an effort to equalize the problem groups with respect to at least one of the individual difference measures. This equalization was necessary in order to establish that problem to-be-solved groups were similar so that if differences were observed they could be attributed to something other than differences in ability.

Subjects were then randomly assigned to one of the four problem sequences such that approximately equal numbers of subjects at the various levels of verbal ability were in each problem sequence group. This was done in an effort to equalize the problem sequence groups with respect to at least one of the individual difference measures.

During the second experimental session, subjects studied and summarized their source analogue during a 6-minute period. During the next 10 minute period, subjects completed a series of multiplication and division problems. This intervening task was deemed necessary in order to dislodge nonpermanent traces of the source analogue from working memory. Immediately following, subjects were given their target analogue. They were asked to study and summarize the target analogue during a 6-minute period and were then given 5 minutes to try and solve the problem. After the initial attempt at solving the target analogue subjects were given a hint. The hint suggested that they think back to the first problem they summarized to see if

that gave them any additional ideas of how they might solve the current problem. After the hint, subjects were given 5 minutes to record a new solution, if any, to their respective problems.

Results

The verbal ability tests were scored for number correct out of fifty. The creativity tests were scored for flexibility, according to the procedures described by Torrance (1974) by two raters, one of whom was naive to the problem sequence assignments. Interrater reliability was acceptable (K = .94). The logic problem was scored for number correct out of twelve. The quality of the summary of the source analogue was scored by two raters, one of whom was naive to the problem sequence assignments, with 97% agreement. Each summary was scored on the number of critical elements of the convergence solution identified. As in Gick and Holyoak (1983) two critical elements were identified: (a) forces converging on the target and (b) multiple small or split forces.

The first analysis tested the hypothesis that subjects would be more likely to provide the convergence solution to the familiar target (the fire fighter). Overall, of the 105 subjects who provided the convergence solution (at either spontaneous or assisted transfer), 56 and 49 subjects provided the convergence solution to the fire fighter problem and technician problems respectively. The hypothesis that the more familiar target would be easier to solve was not supported, $X^2_{(1)} = 1.10$, $p > .05$.

Chi-Square analyses were conducted to determine whether different numbers of subjects were providing the convergence solution in the different problem sequences. One analysis was done for spontaneous transfer and another for assisted transfer. Significantly different numbers of subjects supplied the convergence solution at spontaneous transfer $X^2_{(3)} = 41.67$, $p < .01$. No differences were observed for assisted transfer, $X^2_{(3)} = 3.18$, $p > .05$. These results are summarized in Table 1.

For subsequent analyses, it was critical to establish that the problem sequence groups did not differ on the individual difference variables to be used. Because the interpretation of the results requires comparisons between problem sequence groups based on individual stepwise multiple regression analyses, it is important to substantiate the claim that potential differences are due to something other than differences between subjects in the separate problem sequences. In order to examine this issue, scores on the measures of quality of summary, verbal ability, creativity, and logic problem solving ability were entered as dependent variables in a oneway multivariate analysis of variance (MANOVA) with problem solving sequence (familiar source/familiar target; familiar source/less-familiar target; less-familiar source/familiar target; less-

familiar source/less-familiar target) as the independent variable. No difference in individual difference variables between problem sequence groups was observed (Wilks lambda = .91633), $F(12,458.01) = 1.29$, $p > .05$. Means and standard deviations are pictured in Tables 2 and 3. We fully expected to see no differences on the measures of individual differences between problem sequence groups and problem to-be-solved groups since an attempt was made to equalize the groups before exposure to the problem analogues. This lack of differences allows for opportunities to make comparisons between subsequent individual problem sequence analyses such that dissimilarities between the groups on subjects' ability to solve the target problem may be attributed to something other than differences between sequence groups on the measures of individual differences. That is, because the groups do not differ in quality of source summary, verbal ability, creativity, or logic problem solving ability if different predictors of success are indicated through the stepwise multiple regression analyses, we may be fairly confident that the different contribution patterns between problem sequences is based on something other than an imbalance in the individual difference variables between problem sequence groups.

Stepwise multiple regression analyses were used to determine if individual differences were accounting for ability to solve the target analogue. If a stepwise multiple regression analysis was significant, we were interested in examining the relative contribution of the individual difference variables to prediction accuracy and in identifying different contribution patterns of individual differences between the four problem sequences on the initial attempt to solve the problem (spontaneous transfer) and on a subsequent trial (assisted transfer).

Two stepwise multiple regression analyses were performed on each problem solving sequence and on all data collapsed across problem solving sequences. Scores on the measures of quality of summary, verbal ability, creativity, and logic problem solving ability served as the predictors. Whether subjects provided the convergence solution for the target analogue served as the criterion. One analysis was performed for spontaneous transfer and another for assisted transfer. Data for subjects who were able to spontaneously solve the problem was excluded from the respective assisted transfer stepwise multiple regression analysis. In some instances, assisted transfer stepwise multiple regression analyses should be interpreted cautiously due to small sample sizes. The first analysis reported considers all data regardless of problem sequence. This analysis was conducted to test the preliminary hypothesis that measures of individual differences would serve as powerful predictors of success in solving analogically related problems and to provide a point of reference. The subsequent individual problem sequence analyses serve to examine the more specific hypothesis that different combinations of individual

difference variables would contribute to ability to predict problem solving success between problem sequences.

Overall Analysis. Thirty-four percent of the subjects provided the convergence solution spontaneously. The stepwise procedure resulted in verbal ability entering first (R^2 = .04, B = .248, p < .01) followed by logic problem solving ability (increment in R^2 = .03, B = -.183, p < .01). Quality of source summary and creativity did not seem to make much difference and did not enter.

Thirty-seven percent of the subjects who were unsuccessful on their first solving attempt were able to solve the target analogue with assistance. The stepwise procedure resulted in logic problem solving ability entering first (R^2 = .03, B = .212, p < .05) followed by creativity (increment in R^2 = .04, B = -.191, p < .02). Quality of summary and verbal ability did not enter the analysis.

Familiar Source/Familiar Target (the general--the fire fighter) Problem Sequence. Thirty percent of the subjects correctly solved the target analogue on their first attempt. The stepwise procedure resulted in none of the predictor variables entering the equation. The multiple regression analysis for assisted transfer also resulted in none of the variables contributing to prediction ability. Thirty-nine percent of the remaining subjects were able to solve the target analogue with assistance.

Familiar Source/Less-familiar Target (the general--the technician) Problem Sequence. Only one subject (2.5%) was able to solve the target analogue on the initial trial. As a result, further analysis for spontaneous transfer was inappropriate.

The multiple regression analysis for assisted transfer resulted in none of the variables contributing to prediction ability. Twenty-nine percent of the remaining subjects were able to solve the target analogue with assistance.

Less-familiar Source/Familiar Target (the surgeon--the fire fighter) Problem Sequence. Thirty-three percent of the subjects correctly solved the target analogue spontaneously. The stepwise procedure resulted in creativity entering the equation (R^2 = .12, B = .346, p < .02) with no other variables contributing to prediction accuracy.

Forty-seven percent of the subjects who were unsuccessful on their first solving attempt were able to solve the target analogue with assistance. The stepwise procedure resulted in logic problem solving ability only entering the equation (R^2 = .27, B = .523, p < .01).

Less-familiar Source/Less-familiar Target (the surgeon--the technician) Problem Sequence. Sixty-six percent of the subjects correctly solved the target analogue on their first attempt. The stepwise procedure resulted in verbal ability

entering the equation (R^2 = 14, B = .378, p < .01) with no other variables contributing to prediction accuracy.

The multiple regression analysis for assisted transfer resulted in none of the variable contributing to prediction ability. Thirty-one percent of the remaining subjects were able to solve the target analogue with assistance.

Discussion

The results lend themselves to discussion from a number of perspectives. Because the problem sequence groups did not differ in terms of individual differences, direct comparisons will be made between the groups. First, we will consider the hypotheses stated in the introduction to Experiment 2. After this, an examination of the individual difference variables across the four problem sequences will be made considering differences between familiar and less-familiar source and target analogues. In addition, the discussion will consider differences in spontaneous and assisted transfer. Results from the regression analyses are presented in Table 4 for easier reference.

Overall Analysis

From an overall perspective (all subjects collapsed across problem sequence groups) it is clear that measures of individual differences do contribute to ability to predict whether a subject will provide the convergence solution to a target problem. Further, this prediction ability is seen for both spontaneous and assisted transfer. As anticipated, verbal ability was positively correlated with providing the convergence solution (as shown by the positive beta weight) at spontaneous transfer. Although ability to solve logic problems shows a negative correlation, in retrospect, this is not too surprising. Solving the logic problem required deductive reasoning. Analogy problems require inductive reasoning (Phye, 1990).

When considering the results of the overall analysis for assisted transfer, the relationship between having provided the convergence solution and ability to solve logic problems changes. At assisted transfer, logic problem solving ability shares a positive relationship with having provided the convergence solution.

The new information provided to the remaining subjects in the form of a hint to use information from a previously encountered source may require the subject use his or her deductive reasoning abilities. Although all the information necessary to the solution of the problem is available in the target, (i.e., it is not restricted in the same fashion as the information in the logic problem) more is added, albeit somewhat artificially (i.e., not by the solver him or herself), to the problem representation and the solver has been assisted in moving closer to a potentially correct solution. It may be, in a sense, facilitating the creation

of a new problem representation for the solver. In a means-ends analysis, new problem representations are created as the solver moves successfully through subproblems. For those who are unable to spontaneously solve the problem, the first subproblem may be in knowing where to start or to what they may relate the problem to be solved. The hint coupled with high logic problem solving ability may provide the necessary assistance.

We were, quite frankly, surprised to see a negative correlation between creativity and having provided the convergence solution for assisted transfer. This prompted a post-hoc investigation of the solutions the more creative subjects provided at time of assisted transfer. Two possibilities presented themselves. Both alternatives are based on the premise that the more creative subjects have difficulty recalling the source problem and, as a result, have trouble remembering how the problem was solved. One option is that the more creative subjects elect to provide a second nonconvergence solution because they had more than one solution, perhaps several, in mind at spontaneous transfer. A larger number of potential solutions, if held by the more creative subjects, might put a strain on memory resulting in forgetting the source problem in order to evaluate and select the best solution from those available. The other option is that the more creative subjects do not provide a solution at assisted transfer preferring, instead, to suggest that (a) the solution they provided at spontaneous transfer used the information from the source problem or that (b) the solution they initially provided is better than any other. Further research on these issues might help clarify this confusion.

The results surrounding quality of source summary for spontaneous transfer contradict those of Gick and Holyoak (1983). Recall that Gick and Holyoak found that subjects who created a high quality source analogue summary were more likely to provide the convergence solution at spontaneous transfer. At this point, it should be noted that the quality of the source summary and verbal ability were significantly correlated for the data overall (r = .25, p < .01). As a result, the contribution of verbal ability could be denying quality of source summary the chance to enter the regression equation. Although these results fail to support those of Gick and Holyoak (1983) in suggesting that the quality of summary has an impact on spontaneous transfer, they must be interpreted in light of the correlation between summary quality and verbal ability.

Individual Problem Sequences

The results of the individual problem sequence analyses support some of the hypotheses to a limited degree. As hypothesized, the patterns of contribution to prediction success vary across problem solving sequences and when the measures of individual differences are enhancing prediction of successful problem solving, the contributions were

positive. The discussion continues by considering each individual difference measure in isolation.

Quality of Summary. It appears that the quality of the source summary is not making a contribution to ability to solve the target analogue in the individual problem sequences for either spontaneous or assisted transfer. Although Gick and Holyoak (1983) found that the quality of the source analogue summary did influence whether the convergence solution was provided at time of problem solving, the results of this study are unable to provide additional support for that hypothesis. As in Gick and Holyoak (1983) it appears that quality of summary does not influence ability to solve the target problem when considering assisted transfer.

These results must be interpreted cautiously, however, because only one of the four problem sequences is analogous to the sequence used by Gick and Holyoak. In the Gick and Holyoak studies, the problem solver always attempted to transfer the structure of the general to the surgeon. In the current investigation, the subjects were required to attempt to transfer the structure of the general to the technician. Recall that only one subject was able to spontaneously transfer in that sequence in the current research. Subjects, by and large, find this sequence (familiar source/less-familiar target) extremely difficult as evidence by the low percentages of subjects who provided the convergence solution with (29%) or without (2.5%) assistance. Gick and Holyoak found much higher rates of success in their sequence. We elected not to use the general source/surgeon target in this research because, although that is the predominant sequence in the research literature, pilot testing indicated that of the four problems used, subjects were less likely to automatically supply the convergence solution to the fire fighter and the technician. The results, therefore, may be seen as a better test of transfer than they would have been had we used the general or the surgeon as target analogues.

Verbal Ability. Verbal ability is making a significant contribution to spontaneous transfer in the less-familiar source/less-familiar target sequence. It appears that the ability to see and solve simple analogies (like those in the verbal ability subtest of the Differential Aptitude Test) is an aptitude that subjects are able to apply under varying circumstances (i.e., not just for standardized tests). As expected, verbal ability assumes a significant role in predicting ability to solve analogically related problems when the source and target are less-familiar. This suggests that, under certain conditions, high verbal subjects may be better equipped to solve problems via analogical reasoning on their own (without assistance).

In the less-familiar source/familiar target sequence verbal ability might have been denied the opportunity to make a contribution since verbal ability and creativity are

significantly correlated, $r = .49$, $p < .01$. In this sequence, creativity is contributing to prediction accuracy.

Creativity. Creativity is making a significant contribution to spontaneous transfer in the less-familiar/familiar problem sequence and may be confounded by verbal ability in the less-familiar/less-familiar problem sequence. If it is the case that, as hypothesized, subjects with greater creative ability may be more adept at identifying the underlying structure of the source analogue, then these results are perfectly clear. Subjects with higher levels of creativity are better equipped to identify hidden structures than their less creative counterparts especially when required to move from something that is not very familiar to something that seems moreso. In the less-familiar/less-familiar sequence verbal ability was the only individual difference contributing to prediction potential. It should be noted that for this sequence, creativity and verbal ability are significantly correlated ($r = .45$, $p < .01$). Verbal ability could be masking a contribution by creativity.

Creativity may be making a contribution both in terms of identification of the source and target structures. We have thus far based our hypothesis of the relative merit of creativity on the creative person's ability to see relationships or structures between ideas or objects that other less creative individuals miss. In order for transfer to occur, it is first necessary for the subject to identify the structure that will be transferred or mapped (e.g., Gick & Holyoak, 1983). The creative subjects may be demonstrating: (a) greater success in the initial identification of the source structure; (b) greater success in identification of the structure of the target problem; (c) greater ability to see the relationship between problems and/or structures; or (d) all of the above. In order to transfer the structure from the source to the target, the problem solver must, on some level, acknowledge that a relationship exists between the source and the target. In order to do this, he or she needs to identify the structure in both the source and the target. Creative subjects may be more adept at structure identification and comparison. This is an area that merits further attention.

Logic Problem Solving. In one instance of assisted transfer, less-familiar to familiar, ability to solve logic problems makes a contribution. Recall that for this sequence subjects with higher levels of creativity have already managed to provide the convergence solution. The earlier discussion of how ability to solve logic problems may be contributing to prediction accuracy fits well with this finding.

Familiar and Less-Familiar Source and Target Analogs. When subjects begin with a familiar source, they seem, on the whole, less likely to provide the convergence solution with or without assistance. The overall percentage of subjects who provided the convergence solution spontaneously

or with assistance when starting with a familiar source was 38 whereas 62% provided the convergence solution when starting with a less-familiar source.

Although the quality of summary did not differ significantly between the four problem sequence groups, we noticed when scoring the summaries that subjects who started with a less-familiar source seemed to produce consistently better summaries. That is, when summarizing the less-familiar source more subjects appeared to be including both critical components of the convergence schema in their description. This post-hoc observation was tested via a t-test with source analogue (familiar or less-familiar) as the independent variable and quality of summary as the dependent variable. A significant difference was observed, $t_{(179)} = 2.15$, $p < .05$. Subjects who summarized the familiar source produced poorer quality descriptions than those who summarized the less-familiar source. This suggests that the less-familiar source may encourage more care when encoding and the result is a better quality summary. In other words, the more familiar the content of the source, the less attention paid to it or the less care given to the creation of the summary by the subject. If more care had been given to the summary by more subjects (as determined by quality of summary) who started with the familiar analogue, quality of summary might have made a contribution to ability to predict for those sequences. Further, higher levels of successful transfer might have been observed. In effect, it appears that the familiarity of the source may be the critical issue when considering transfer.

Even though quality of source summary did not make a significant contribution to ability to predict for any of the problem sequences, it should not be disregarded in future endeavors. This post-hoc observation fits well with the hypothesized function of summary of source analogue. Recall that Gick and Holyoak suggested that better quality summaries may be evidence of a more elaborately encoded schema for the problem structure. In the present study, it appears that a high quality summary, while helpful, may not be sufficient for transfer. Other differences between subjects may also account for success in transfer.

Spontaneous and Assisted Transfer. Varied combinations of individual differences are making contributions to spontaneous transfer for two problem sequences (remember, though, that a regression analysis was inappropriate for the less-familiar/familiar sequence). When prediction of spontaneous transfer is considered for these two sequences, the relative contribution of individual difference variables shifts.

Individual differences do not appear to influence ability to solve the target problem when assistance has been provided in the form of a hint with one exception. In effect, it seems that the hint plays an equalizing role. The only exception in the current study was when subjects attempted to transfer from a less-familiar knowledge domain

to a more familiar knowledge domain. The major contributor was ability to solve logic problems (see earlier discussion).

General Comments and Implications

According to Gick and Holyoak (1983) the critical element in transfer is identifying the structure of the source schema. For the most part, the research emphasis in transfer and problem solving has examined the relationships between surface and structural similarities between problem sources and targets. This study, structural similarities notwithstanding, suggests that the difference in an subject's ability to identify that structure may lie in a linear combination of measurable individual differences. Under identical problem sequences we see verbal ability or creativity making a significant contribution to prediction accuracy. Evidently differences in ability between subjects accounts for their ability to identify that critical structure under certain circumstances.

We hypothesized that individual differences would contribute to ability to solve analogically related problems. This hypothesis was provided limited support for spontaneous but not for assisted transfer when subjects have a less-familiar scenario as their source for the analogue structure. In addition, our expectation that different combinations of individual difference variables would contribute to knowledge transfer was upheld. It would appear that having access to and carefully encoding a less-familiar source promotes transfer. If this is coupled with high verbal or high creative ability (depending on the familiarity of the target) the result is successful transfer.

All of the implications of this study are not completely clear. The mechanisms underlying successful transfer are elusive or, to paraphrase Anderson (1990), transfer via analogy does not happen by chance. Nevertheless, we were left with several impressions and suggestions for further inquiry. Of the individual difference variables included in this study, verbal ability and ability to solve logic problems are probably the most difficult to enhance. Enhancing creativity and encouraging closer attention to source analogs, however, is possible. Glover and associates (e.g., Glover & Gary, 1976; Glover & Sautter, 1977), for example, found that students from grade school through and including college could be encouraged to make more flexible responses to variations of the Unusual Uses Test. Perhaps a result of this creativity enhancement would be greater ability to identify the structure of a source schema and, therefore, greater success in transfer.

Methods other than summarizing the source analogue might result in identification of the critical elements of the problem structure. Summarizing a source in order to carefully encode the schema is only one of several options.

On an individual basis, subjects could be asked to paraphrase the summary (which is what some, but not all, seem to do when asked to summarize) or answer questions about the source. Gick (1985) has continued research in a graphic vein and has had subjects look at diagrams that represent the convergence schema. In settings more akin to classroom instruction, subjects could discuss the source form any number of perspectives. The directions research of this nature could take are seemingly limitless.

Gick and Holyoak (1983) found that providing subjects with two source analogs resulted in greater success in solving a target problem. Individual differences may also play an important role under these conditions. Further, because Gick and Holyoak did not consider different problem sequences (e.g., crossing from less-familiar to familiar) a wide range of problem sequences are available for inspection.

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Table 1

Number of subjects solving transfer problem with the convergence solution (percentage in parenthesis) by problem sequence for spontaneous and assisted transfer.

Problem Sequence	Spontaneous Transfer (Before Hint)	Assisted Transfer (After Hint)
Overall	61 (34.0)**	44 (37.0)**
Familiar/Familiar	14 (30.0)	13 (39.0)
Familiar/Less-familiar	1 (02.5)	12 (29.0)
Less-familiar/Familiar	15 (33.0)*	14 (47.0)**
Less-familiar/Less-familiar	31 (66.0)**	5 (31.0)

* Multiple regression analysis significant, $p < .05$.
** Multiple regression analysis significant, $p < .01$.

Table 2

Means, Standard Deviations, and sample sizes for verbal ability, creativity, logic problem solving, and quality of summary by problem solving sequence with a familiar source analogue.

	Problem Sequence			
	Familiar Source Analogue			
	Target Analogue			
	Familiar (n = 46)		Less-familiar (n = 43)	
Variable	M	SD	M	SD
Quality of Summary	1.21	0.75	1.09	0.70
Verbal Ability	34.61	8.82	34.56	8.89
Creativity	15.65	7.31	15.14	6.97
Logic Problem Solving	7.17	4.05	7.33	3.82

Table 3

Means, Standard Deviations, and sample sizes for verbal ability, creativity, logic problem solving, and quality of summary by problem solving sequence with an less-familiar source analogue.

	Problem Sequence			
	Less-familiar Source Analogue			
	Target Analogue			
	Familiar (n = 45)		Less-familiar (n = 46)	
Variable	M	SD	M	SD
Quality of Summary	1.27	0.78	1.36	0.76
Verbal Ability	34.49	8.81	35.40	9.43
Creativity	13.11	5.70	12.02	6.37
Logic Problem Solving	6.87	3.62	6.36	3.55

Table 4

R^2, change in R^2, and beta weights for the multiple regression analysis by problem sequence for spontaneous and assisted transfer.

Problem Sequence	Spontaneous Transfer (Before Hint)			Assisted Transfer (After Hint)		
	R2	R2 change	B	R2	R2 change	B
Overall						
Verbal ability	.04	.04	.284	---	---	----
Logic problem	.07	.03	-.183	.03	.03	.212
Creativity	---	---	----	.07	.04	-.191
Source summary	---	---	----	---	---	----
Less-familiar/Familiar						
Creativity	.12	.12	.346	---	---	----
Logic problem	---	---	----	.27	.27	.523
Verbal ability	---	---	----	---	---	----
Source summary	---	---	----	---	---	----
Less-familiar/Less-familiar						
Verbal ability	.14	.14	.378	---	---	----
Source summary	---	---	----	---	---	----
Logic problem	---	---	----	---	---	----
Creativity	---	---	----	---	---	----

Note: The values are reported only for regression analysis which yielded significance.

Appendix A

Logic Problem

COUNTER INTELLIGENCE

A block of four shops is to be found in the High Street. From the clues given below, can you fill in on the plan the full name of the owner of each shop and the nature of his business?

Clues

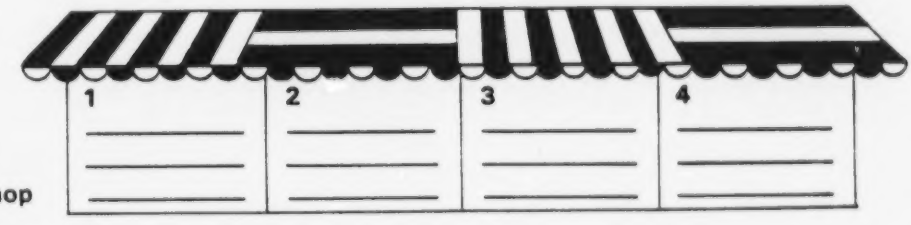
1 The chemist's shop is no. 2.

2 Henry is the proprietor of the clothes store, which is next door to the record shop, whose proprietor is not John Franks.

3 William's shop is between the shop run by Peters and the greengrocer's.

4 No. 4 is owned by Richards, who is not Fred.

5 One of the proprietors is called Jones.



Appendix B

Source and Target Analogues

Familiar Knowledge Source: The General

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small groups of people could pass over them safely, since the dictator needed to move his troops and workers to and from the fortress. However, a large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress.

The general, however, devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

Less-familiar Knowledge Source: The Surgeon

A patient has been complaining about stomach problems for a considerable period of time. A number of tests are run and it is discovered that the patient has a malignant tumor in his stomach. A specialist is called in to treat this patient. The specialist knows that it is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is, however, a kind of ray that can be used to destroy the tumor. If the ray reaches the tumor at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the ray passes through on the way to the tumor will also be destroyed. At lower intensities the ray is harmless to healthy tissue, but it will not affect the tumor either. A full intensity dosage of the ray appeared impossible.

The specialist, however, was undaunted. She divided the ray into a larger number of lower intensity rays and positioned them at multiple locations around the patient's body. All of the lower-intensity rays passed harmlessly through the healthy tissue and converged on the tumor at full strength. In this way, the specialist was able to destroy the tumor and save the patient's life.

Familiar Knowledge Target: The Fire fighter

An oil well in Saudi Arabia exploded and caught fire. The result was a blazing inferno that consumed an enormous quantity of oil each day and threatened to destroy the neighboring villages. After initial efforts to extinguish it failed, you are called in. You know that the fire can be put out if a huge amount of fire retardant foam can be dumped on the base of the well. There is enough foam available at the site to do the job, however, there are no hoses large enough to put all the foam on the fire fast enough. The small hoses that are available can not shoot the foam quickly enough to do any good. It look like there will have to be a costly and potentially catastrophic delay before a serious attempt can be made to extinguish the fire. What type of procedure might you use to extinguish the fire with materials already available at the fire site and at the same time keep the fire from destroying the neighboring villages?

Less-familiar Knowledge Target: The Technician

In a physics lab at a major university, a very expensive light bulb which would emit precisely controlled quantities of light was being used in some experiments. Suppose you are the research assistant responsible for the operation of the sensitive light bulb. One morning you come into the lab and find to your dismay that the light bulb no longer works. You realize that you had forgotten to turn it off the previous night. As a result the light bulb overheated, and the two wires in the filament inside the bulb have fused together. The surrounding glass bulb is completely sealed, so there is no way to open it. You know that the light bulb can be repaired if a brief, high-intensity ultrasound wave can be used to jar apart the fused parts. Furthermore, the lab has the necessary equipment to do the job. A high-intensity ultrasound wave, however, would also break the fragile glass surrounding the filament. Unfortunately, at lower intensities the ultrasound wave will not break the glass, but neither will it jar apart the fused parts. What type of procedure might you use to jar apart the fused parts with the ultrasound wave and at the same time avoid the necessity of buying a costly replacement bulb?